Assessing the impact of ERP on supplier performance

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Abstract

Purpose – Through an empirical study, this paper identifies a multitude of drivers that facilitate or hinder the implementation of enterprise resource planning (ERP) in business environments. Also, the purpose of this paper is to analyze its role in supply chain operations and assesses its impact on supplier capabilities and performances from supply chain perspectives.

Design/methodology/approach – Based on both a contingency theory and a resource-based view (RBV) of the firm, the research develops a series of hypotheses regarding the use of ERP for strategic sourcing. A large-scale survey of Korean manufacturers and their suppliers was conducted. A structural equation model was used for data analysis.

Findings – The firm's external environment (EE) has little influence on its decision to adopt and implement ERP. However, through the mediating role of an internal environment (IE), an EE still indirectly influences the ERP adoption and ERP implementation (ERPI) decision. Also, the paper found that ERP could enhance the ERP adopter's supplier capability (SCAP).

Originality/value – This study investigates the role of ERP in the supply chain and identifies important determinants influencing the ERP adoption and implementation decisions. Especially, this paper assesses the benefits of ERP from the ERP adopter's supply chain partner's standpoints.

Keywords Enterprise resource planning, Supply management, Structural equation modelling, Manufacturing resource planning, Supply chain management

Paper type Research paper

1. Introduction

Riding on the reengineering movement of the 1990s, enterprise resource planning (ERP) has emerged as one of the major breakthrough information technologies that can re-shape the manufacturing industry. Despite some missteps and implementation failure, the popularity of ERP continued to increase for the last few years. As a matter of fact, the ERP market grew from $28.8 billion in 2006 to $47.5 billion in 2011 and is expected to grow to an estimated $67.7 billion by 2017 (Jacobson *et al.*, 2007; Lucintel, 2013). The ERP spending in 2012 rose by 4.5 percent compared to 2011 (Low, 2012). Reflecting this trend, almost three quarters (72 percent) of the manufacturers recently surveyed by the Aberdeen Group (2011) are currently using ERP for their operational efficiency and subsequent organizational growth. This continued popularity of ERP has been attributed to its ability to process transaction information faster, track product orders and inventory, automate orders and payments, lower setup costs, reduce order cycle time, avoid data duplication, and integrate business processes

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throughout the entire supply chain (Trott and Hoecht, 2004; O'Leary, 2004). In other words, ERP can enhance supply chain visibility and subsequently improve supply chain efficiency. Evolved from manufacturing requirement planning, ERP is generally referred to as a cutting edge information technology that helps the firm coordinate and integrate company-wide business processes including sales, marketing, manufacturing, logistics, purchasing, accounting, and human resources management using a common database and shared management reporting tools (Brady *et al.*, 2001). In a sense, ERP is a "dashboard" that provides some levels of central oversight and controls that are needed to ensure that all of the company's resources are working together towards the same goal.

In particular, ERP can play a significant role in managing the supply chain, since ERP is known to improve inventory record and bills of materials accuracy, achieve on-time delivery services, and reduce pipeline inventory throughout the supply chain (Buker, Inc. Management Education and Consulting, 2011). Despite aforementioned potential benefits, some firms are still hesitant in utilizing ERP to improve supply chain operations for many reasons. These reasons may include: longer payback periods resulting from exorbitantly expensive ERP implementation (ERPI), a lack of user friendliness of ERP systems, incompatibility among multiple versions of ERP software/hardware, poor data bases, a difficulty in providing a seamless interface to different business units, and organizational resistance to change. The adoption of ERP in the supply chain setting depends heavily on the firm's ability to overcome a host of inhibitors or make a compelling case for the dramatic improvement in supply chain efficiency. Therefore, there is a need to identify key drivers of ERP which can improve the return-on-investment of ERP from supply chain perspectives and then provide guidance for those who would like to improve its ERP applications to supply chain management (SCM) or those who may consider using ERP for SCM improvement in the future.

The main objectives of this paper is threefold: to identify both critical success factors (both endogenous and exogenous) most essential for successful ERP applications to SCM; to evaluate the seriousness of obstacles for implementing ERP for SCM operations; and to assess the impact of ERP on supplier capabilities and performances from a SCM standpoint. Therefore, this paper intends to provide SCM perspectives in understanding both the key drivers of successful *ERPI* and the role of ERP in SCM.

2. Prior literature

If successfully implemented, ERP can create value in a number of different ways by integrating the firm's multifarious business activities into a single system, facilitating organizational standardization, increasing access to online and real time information, improving intra- and inter-organizational communication and collaboration, and enhancing decision-making capabilities (O'Leary, 2000). ERPI, however, poses enormous managerial challenges not to mention high cost of start-up investment. The failure to deal with these challenges often spells disaster as illustrated by the ERP nightmares of Hershey foods, Nike, HP, and waste management. To help ERP adopters avoid similar disasters, most prior studies on ERP (Zhang *et al.*, 2002; Nah and Delgado, 2006; Ulrich, 2007) have focused on the identification of critical success factors for ERPI. Much of these earlier studies attempted to uncover the main sources of ERPI failures and successes. These sources include: top management commitment, project management, changes in organizational culture, data accuracy, user training, user involvement, multi-site applications, ERP software vendor support, perceived usefulness, and perceived ease of use. In addition, other studies (Hong and Kim, 2002; Morton and Hu, 2008) reported that organizational fit, internal restructuring, and pre-implementation attitudes can influence the ERPI success. The key research framework that these studies used is similar to a technology acceptance model (TAM) introduced by Davis (1986) which aims to examine how prospective user behavior, attitude, and his/her external environments (EEs) influence technology adoption decisions. This kind of research framework, however, is not designed to understand how ERP adoption impacts the firm's business performances, nor does it assess the extent of ERP impact on business outcomes.

Recognizing such a shortcoming, O'Leary (2004) examined the potential benefits to be gained from ERPI based on empirical analysis. These benefits include: enhanced visibility, improved customer responsiveness, reduced inventory, labor savings, higher productivity, and improved order management. He found that the extent of these benefits, however, varied across the industry. Bendoly and Schoenherr (2005) also found that ERP brought a number of benefits such as the elimination of process bottlenecks, elimination of (data) redundancy, transaction time reduction, and standardized interfaces between human and computer. In particular, they discovered that the firms with a longer history of ERP usage garnished greater benefits (especially B2B e-procurement cost savings) than the firms with a shorter history of ERP usage. Similar to the finding of Bendoly and Schoenherr (2005) and Gattiker and Goddhue (2005) found that the impact of ERP on task efficiency improved over time but at a decreasing rate. They also found that the customization of ERPI improved the task efficiency at the plant level, since ERP benefits might vary from one plant to another. In other words, without tailoring ERP for the unique setting of each plant, some benefits of ERP may not fully materialize. Considering the evolving benefits of ERP, Schubert and Williams (2009) focused on the evaluation of ERPI benefits over time by dividing the ERPI phases into *ex ante* (ERP selection and introduction) and *ex post* (actual ERP use, upgrade, and possible replacement) implementation phases. Although these prior studies realized variations in ERP benefits depending on the industry, timeline, organizational setting, and a functional area, they did not investigate how significantly ERP can affect the supplier capability (SCAP) and performance from a supply chain perspective. The dearth of the published literature regarding the ERP applications in SCM lies in the difficulty of assessing the ERP impact from the perspective of multiple supply chain partners (e.g. both the focal company and its suppliers) representing different values and corporate goals as opposed to the context of a single focal company.

To fill the void in aforementioned prior studies, this paper investigates both endogenous and exogenous variables (factors) that dictate the ERP success, examines what roles ERP plays in enhancing the focal company's sourcing capabilities, and assesses the impact of ERP on the focal company's suppliers' capabilities and competitive advantages. This paper is one of the first to provide a holistic view of ERP impacts on supply chain (especially sourcing) operations based on contingency theory and a resource-based view (RBV) of the firm theory.

3. Theory development and hypotheses

To examine which factors drive the ERP adoption and gauge the level of ERP success, we employed two well-known theories in the strategy literature: contingency and RBV of the firm. To elaborate, contingency theory aims to investigate how environmental variables influence the behaviors of organizations (Lawrence and Lorsch, 1967; Chandra and Kumar, 2000). Contingency theory is predicated on the premise that the firm's strategy, including information and communication technology (ICT) adoption strategy, depends on its endogenous and exogenous business environments (Donaldson, 2001). In highly turbulent business environments where a firm faces difficulty in recognizing the needs and preferences of its customers due to a greater uncertainty, access to accurate and timely information needed for a strategic decision can dictate the success of the firm (Citrin *et al.*, 2007). As such, ICT adoption/investment is essential for improvement of the firm's performances in highly turbulent business environments. On the other hand, a firm which is resistant to any changes, reluctant to bear risk, or not ready to embrace new ICT for technical or economic reasons, may not be a good fit for ICT adoption. Therefore, contingency theory may help the firm understand what truly drives the ERP adoption and then identify a set of external and internal environmental variables influencing the firm's ERP success.

A RBV of the firm theorizes that a firm which possesses a bundle of unique resources (e.g. assets, human capitals, capabilities, organizational process, information, knowledge) can improve its performances and subsequently achieve competitive advantages in the market. To put it simply, RBV theory is predicated on a premise that the firm competes on the basis of "unique" corporate resources that are valuable, rare, difficult to imitate, and non-substitutable (VRIN) by competitors (Barney, 1991; Wade and Hulland, 2004). Considering that ERP can be regarded as a unique corporate resource, RBV theory may be useful for explaining how ERPI improves the firm's capabilities and performances.

3.1 Defining the research model and constructs

Under both the contingency and RBV theories described earlier, we develop a research framework that is comprised of five constructs: an EE, an internal environment (IE), ERPI, SCAP, and supplier performance (SPERF). Herein, the EE is generally referred to as exogenous factors (physical and social) that form the context for organizational actions and decision making (Li *et al.*, 2006). Even though the firm has little or no control over its EE, a greater awareness of its EE helps the firm better adapt and develop appropriate ICT adoption strategies (Lusthaus *et al.*, 1999). The EE surrounding the ERPI includes technological change and market change.

An IE is referred to as an organization's endogenous resources and capabilities. A mere command of some central authority, such as an executive or a senior manager, alone cannot make ERPI successful. ERPI requires effective, committed, and persistent leadership to achieve the goals of an entire firm. Therefore, to successfully implement ERP, the firm should consider its organizational readiness and resource capabilities defined by endogenous factors such as top management support, organizational culture, communication, business process reengineering, and ICT readiness. Many researchers emphasize the importance of top management support, business process reengineering, and communication during ICT implementation (Buckhout *et al.*, 1999). To elaborate, top management support is critical for an ERP project's success given the required resource commitment (Buckhout *et al.*, 1999; Loh and Koh, 2004). Also, the firm's inclination for open communication which can facilitate information sharing can make ERPI successful (Motwani *et al.*, 2002). Furthermore, organizational culture is regarded as one of the critical success factors for an ICT success, since the organization culture has profound effects on the ICT planning process, the implementation process, and the follow-through operation of the completed project (Stewart *et al.*, 2000). In particular, Jones *et al.* (2006) discovered that organizational culture directly affected the ERPI team's ability to share knowledge and perspectives across the different functional units of the firm.

The ERPI is defined as a firm's extent to adapt, configure, and integrate the information flow and business processes necessary to support different departments and functions in an organization through the use of ICT architecture that collects and stores data in real time (Hong and Kim, 2002; Loh and Koh, 2004; Klein, 2007). Essential elements for ERPI include: the integration of different modules, software, and legacy systems to achieve unity in an organization, matching the software to the needs of organizational processes, adjusting new technology to cope with changes, and preparing and developing the ICT workforce (Hong and Kim, 2002; Morton and Hu, 2008).

SCAP is referred to as a suppliers' ability to utilize its resources to meet its buying firm's needs and business goals. One example of such capability may include the supplier's ability to coordinate its production operations with its buying firm based on the end-customer demand information provided by its downstream supply chain partners. Also, the supplier can participate in new product development through an early supplier involvement program offered by its buying firm. A basic enabler for this kind of close coordination and cooperation is information sharing, which can be facilitated by advances in ICT such as ERP. For example, joint demand forecasting by the buying firm and its suppliers within the ERP framework can reduce inventories and improve resource utilization throughout the supply chain. SCAP is comprised of information access, process improvement, and product innovation.

SPERF is referred to as the extent of the supplier's ability to deliver materials, components, or products to its buying firm in accordance with the buying firm's needs and requirements (Shin *et al.*, 2000). SPERF has significant impact on the buying firm's operational success, since the supplier's poor incoming product quality and erratic delivery often lead to a higher level of inventory and order backlogs (Li *et al.*, 2006). Generally, SPERF can be classified into four categories: short lead time, product variety, cost and quality (Shin *et al.*, 2000).

3.2 Hypotheses development

In the earlier sub-section, the literature was reviewed to establish the content validity of each construct. Our review of the literature suggests that four constructs (*EE*, *IE*, *ERPI*, and *SCAP*) can potentially influence the focal company's suppliers' performance as shown in Figure 1. To identify factors that are essential for the successful implementation of ERP and assess their impact on the focal company's suppliers' performance, we developed a number of hypotheses and then tested their validity using empirical data. In the following section, the rationale for these hypothesized relationships is described in detail.

3.2.1 EE and IE. Gordon (1991) and Nahm *et al.* (2003) found that the EE and the IE of an organization were loosely coupled. For instance, Swamidass and Newell (1987) empirically proved that environmental uncertainty was positively related to top management pursuit of flexibility and centralized decision making that shape up the IE. As such, the firm facing a volatile EE tended to have more frequent communication among its internal units than those in a stable EE (Lawrence and Lorsch, 1967;

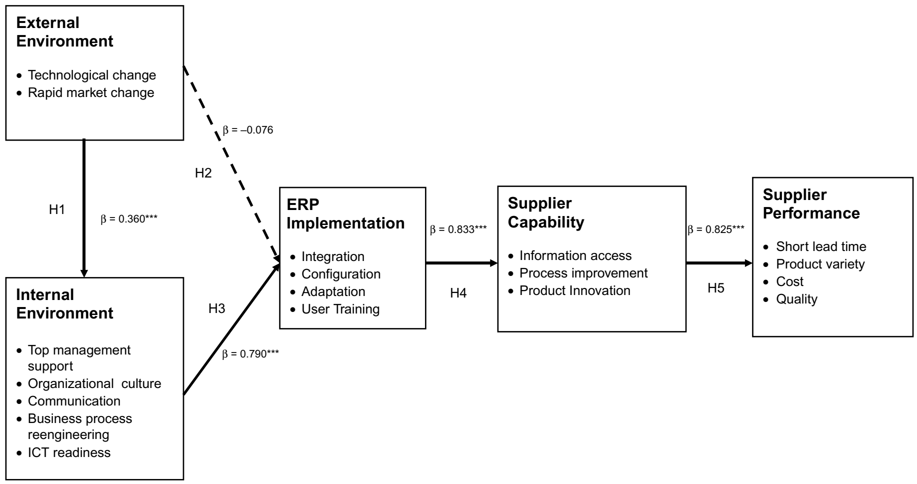

Figure 1.
The research model and results of AMOS analysis

Duncan, 1972). In other words, the amount of work-related communication allows the firm to reduce uncertainty with more accurate and timely information transmitted through frequent communication. Also, a rapid advance in ICT would help the firm improve technological readiness for innovative ICT such as ERP and thus revitalized the firm's IE (Lee *et al.*, 2007). Therefore, we hypothesized that:

H1. A firm which operates in volatile market environments characterized by technological changes tends to foster IEs conducive for ERP success.

3.2.2 EE and ERPI. The EE is known to be one of the key drivers for ICT implementation (Lawrence and Lorsch, 1967; Chandra and Kumar, 2000). More specifically, Mentzer *et al.* (2000) suggested that rapid technological changes would allow the firm to leverage innovative ICT and thus would encourage the firm to share information with its suppliers so that both the buying firm and its supplier could reduce uncertainty in volatile EEs. For example, a retail giant, Wal-Mart and its supplier, Warner-Lambert, shared sales and demand forecast information through their collaborative planning, forecasting, and replenishment system and then successfully reduced both companies' inventory while preventing out-of-stocks (Seifert, 2003). Also, the increased focus on customer services would compel organizations to learn more about the changing demands and preferences of customers and thus increase the need for adopting ERP. As a matter of fact, Grover and Goslar (1993) and Kim and Lee (2008) found that companies in more fluid environments make more effort to adopt and implement ICT successfully than those in stable environments. Therefore, we hypothesize that:

H2. The firm operates in volatile environments characterized by technological changes are more likely to adopt and implement ERP.

3.2.3 IE and ERPI. Without organizational readiness and proper change management, ERPI is doomed to fail (Motwani *et al.*, 2002). Considering the importance of organizational compatibility to successful ERPI, Zhang *et al.* (2002) listed five critical success factors for ERPI: top management support; people characteristics, including education, training and user involvement; suitability of software, hardware and data accuracy; ERP vendor commitment; and organizational culture. In particular, top management's willingness to commit the company's both financial and human resources to an ERP project could dictate the organizational readiness for the ERPI (Kwahk and Lee, 2008). Also, the firm's organizational culture that could foster and reward open communication and frequent interaction among the firm's employees turned out to be an important prerequisite for successful ERPI, since it would improve ERP-related problem-solving capability (Stewart *et al.*, 2000; Jones and Price, 2001). Indeed, the firm with a more adaptive organizational culture characterized by "fluid job descriptions, loose organizational structures, and few restrictive rules" is most likely to succeed in implementing innovative ICT such as ERP (Brown and Eisenhardt, 1997). Furthermore, user education and training enhances the user's familiarity with ERP and thus users will be more willing to embrace ERP (Loh and Koh, 2004). ERP vendor commitment enhances the ICT staff's ability to configure and maintain ERP and thus make transition from the legacy system to ERP system smoother. Therefore, we hypothesize that:

H3. The more a firm is internally ready for a technological change, the more successful ERPI will be.

3.2.4 ERPI and SCAP. The ERPI which connects a firm to its suppliers will enhance information integration and coordination between the firm and its suppliers. Through information integration and coordination facilitated by ERP, a supplier can share operational, tactical, and strategic information with its downstream supply chain partners and subsequently can improve its sourcing capability and their performance (Shin *et al.*, 2000). To elaborate, Seidmann and Sundarajan (1997) observed that a supplier's willingness to share information with its buying firm could help it to leverage managerial knowledge and expertise across the supply chain. Indeed, information sharing allows the supplier to improve its demand forecasts, synchronize its production and logistics activities, coordinate inventory-related decisions, avoid bottlenecks, and mitigate the bullwhip effects (Lee and Whang, 2000). As such, information sharing between the supplier and its buying firm improves the supplier's visibility and the subsequent capability to meet its demand and delivery schedules (Handfield and Bechtel, 2002).

In other words, when accurate and real-time demand information becomes available from ERP, the supplier can better react to changing demand patterns and thus more readily identify what customers really want and need. For example, a buying firm's ERPI which can transmit necessary demand information to its supplier may facilitate new product development (or product innovation), while streamlining product and logistics processes. The availability of such information enables the supplier to change its product volume and mix in a relatively short period of time and thus help the supplier consistently accommodate the buying firm's changing sourcing requirements. From the above, we can make a premise that the ERPI enables the supplier to speed up its response to rapidly changing business environments and consequently improve the supplier's capability including greater information access, process improvement, and product innovation. Therefore, we hypothesize that:

H4. The higher the level of ERPI, the higher the level of a supplier's capability.

3.2.5 SCAP and SPERF. Through improved connectivity facilitated by ERPI, ERP could strengthen a relationship between the buying firm and its supplier and thus increase the chance that the buying firm will offer long-term contracts for its supplier. This strengthened relationship resultant from long-term contracts would increase stability for the supplier. With a greater stability, the supplier can afford to make long-term investments in research and development (R&D) efforts and engage in continuous quality improvement processes. Also, through inter-firm cooperation and collaboration facilitated by ERP, the supplier could streamline its organizational processes and subsequently enhance its organizational performance (Bello and Gilliland, 1997). Notice that knowledge and information obtained from the buying firm through ERP links could improve the supplier's business acumen and stimulate the supplier's new product development and value-adding processes (Thatte *et al.*, 2008). That is to say, the ERPI which facilitates greater information access, process improvement, and product innovation may enhance SPERF and the supplier's competitiveness in the marketplace. Therefore, we hypothesize that:

H5. The higher the level of SCAP, the higher the level of SPERF.

4. Research methodology

To address the aforementioned research questions, we carried out the current study in three phases. First, we generated potential survey items predicated on theory built by the prior ERP literature. Second, we develop a structural equation model (SEM) along with the identification of valid constructs based on structural interviews with selected ERP users and the Q-sort method. Finally, we conducted a large-scale survey via mail questionnaires primarily targeting Korean industry comprised of manufacturers and their suppliers. Using the survey data, we employed the path analysis approach with AMOS to test the validity of the proposed SEM. Specific details of the current research methodology are described below.

4.1 Questionnaire survey and sample characteristics

In the pre-pilot stage, a total of 140 questionnaire items were distributed to six academic reviewers with ERP expertise in the US (e.g. publication records in the ERP literature), who reviewed each item and indicated to keep, delete, or modify them. The focus of this analysis was to assess whether the items were thought to accurately measure the proposed sub-constructs according to the definitions provided, and if any additional domains needed to be covered. After deleting and purifying a number of items based on the feedback from the reviewers, 120 items were used as the large-scale questionnaire survey. Via e-mail, a survey questionnaire containing these items was sent to 593 randomly selected Korean manufacturing firms listed on the KOSPI and KOSDAQ Stock Market. More than 88 percent of the survey respondents are managers or upper management that actively used ERP at the time of survey (Table I). To increase variability in the data and generalizability of the survey results, the instrument was targeted for eight different sectors of Korean manufacturing firms. These industries included: food and kindred products; paper and allied products; chemicals and allied products; stone, clay, glass, and concrete products; fabricated metal products; industrial machinery and equipment; electronic and other electric equipment; transportation equipment.

Of the 593 questionnaires, 205 valid responses were received. These responses produced a total response rate 34.6 percent which had surpassed the targeted overall

		Percent
	(1) Respondents by SIC code	
SIC code	*Name*	
20	Food and kindred products	8
26	Paper and allied products	6
28	Chemicals and allied products	20
32	Stone, clay, glass, and concrete products	7
34	Fabricated metal products, except machinery and transportation	18
35	Industrial and commercial machinery and computer equipment	14
36	Electronic and other electrical equipment and components	14
37	Transportation equipment	13
	Total	100
	(2) Respondents by position	
Position		
Directors		1
General manager		10
Deputy general manager		16
Managers		46
Assistant manager		26
Staff		1
Total		100
	(3) Firms by size	
Number of employees		
Less than 100		8
100 to 249		25
250 to 499		26
500 to 999		20
1,000 to 2,499		10
2,500 and over		11
Total		100
	(4) Product complexity	
Product complexity		
Very low		4
Low		7
Moderate		38
High		38
Very high		13
Total		100

Table I.
Description of sample

response rate of over 20 percent for a valid assessment. For example, Malhotra and Grover (1998) observed that a response rate over 20 percent was needed for a positive assessment of questionnaire survey results. 8 percent of the responding firms had less than 100 employees and 25 percent of the responding firms have 100 to 249 employees. The firms employed between 250 and 499 individuals accounted for 26 percent of the respondents, while the firms with between 500 and 999 employees accounted for 20 percent of the respondents. Approximately 10 percent of the responding firms had between 1,000 and 2,499 employees, while 11 percent of the responding firms had more than 2,500 employees. More than half (51 percent) of the respondents said the level of complexity of their products was above average ("high" – 38 percent or "very high" – 15 percent). More than one-third (38 percent) of the respondents represented manufacturing firms with moderate product complexity. Product complexity was reflected by the number of product variants a firm produces. Since the degree of product complexity was tied to the complexity of working environments, the firms with a high level of product complexity were likely to utilize ERP (Table I).

4.2 Non-response bias test

Considering the potential non-response error associated with a questionnaire survey, we conducted a χ^2 test of homogeneity for non-response bias by comparing the SIC group distribution for the sample population and total responses (Armstrong and Overton, 1977). There were no statistically significant differences in group means for the eight different industry samples at $\alpha = 0.05$ on any of the item responses described earlier. Therefore, non-response bias did not appear to be a concern.

5. Analysis and results

To examine causal relationships among the construct, we tested the five proposed hypotheses with valid and reliable scales that measured some critical dimensions of EE, IE, ERPI, SCAP, and SPERF. A SEM framework was used to explore a relationship among the constructs and to test the hypotheses (Bollen and Long, 1993). The proposed SEM consists of two elements:

(1) a measurement model which is used to measure and assess the reliability and validity of latent variables; and

(2) a structural model which is applied to investigate the complex interrelations among latent variables (Jöreskog and Sörbom, 1989).

Since the reliability and validity of each construct were checked earlier through rigorous analysis, the SEM analysis focused on the structural model. To explore relationships among EE, IE, ERPI, SCAP, and SPERF, the AMOS software was used. Since it would be better to use several indicators of a construct than a single indicator, we used composite measures as multiple indicators for each construct (Hair *et al.*, 2009). Composite measures were calculated by dividing the sum of individual scores of items in each sub-construct by the number of items. These composite measures were used as observable indicators of the exogenous latent construct (EE) and endogenous latent constructs (IE, ERPI, SCAP and SPERF).

5.1 Measurement model, validity, and reliability

Initially, we test the measurement model and establish the validity and reliability of the items using confirmatory factor analysis. EE, IE, ERPI, SCAP and SPERF are hypothesized as a second-order construct. Therefore, we conduct this first step analysis in three stages. In stage 1, we conduct confirmatory factor analysis at the first-order level for all the constructs in our model – this measurement model is referred to as the first-order measurement model. In stage 2, we validate the second-order specification for the sub-dimensions of EE, IE, ERPI, SCAP and SPERF. In the final stage3, we conduct confirmatory factor analysis of all the items representing EE, IE, ERPI, SCAP, and SPERF as second-order constructs (i.e. the second-order measurement model). Table II presents the fit statistics for the first- and second-order measurement models. Table III presents the fit statistics for the EE, IE, ERP, SCAP and SPERF measurement models to help validate the second-order

Fit statistic	Measurement model (first-order)	Measurement model (second-order)	Recommended values
χ^2	2,022.862	2,277.732	
Df	1,555	1,680	
RMSEA	0.038	0.042	$\leq$0.08 marginal fit; $\leq$0.05 good fit
CFI	0.950	0.936	
NNFI	0.943	0.933	$>$0.8 marginal fit; $>$0.9 good fit
IFI	0.951	0.937	
SRMR	0.046	0.067	$<$ 0.09

Note: $n = 205$
Sources: Browne and Cudeck (1993); Hu and Bentler (1998, 1999); Handley and Benton (2009)

Table II.
Fit statistics for validating the measurement model

specifications of all five second-order constructs. Tables IV and V present the inter-factor correlations, average variance extracted and reliability measures for the first- and second-order measurement models.

We first assess the overall fit of the first-order measurement model. In line with Shah and Goldstein (2006)'s recommendation, multiple fit indices are used to assess model fit. The fit indices indicate an acceptable fit for the overall model with all values are above the range for acceptable fit and with multiple values (GFI, CFI, NFI, IFI, RMSEA and SRMR) indicating a good fit. Convergent validity may be assessed by checking the significance of the loading for an item on its posited underlying construct (Gerbing and Anderson, 1988). The loadings for the first-order measurement model indicate that all the items load significantly on their posited constructs. Table IV presents the inter-construct correlations and the values for average variance extracted for the first-order measurement model. Discriminant validity can be assessed by examining if the average variance extracted by the items of the construct is greater than the average shared variance (square of the correlations in the off-diagonals) between two constructs (Fornell and Larcker, 1981).

All constructs pass this test supporting discriminant validity. The Cronbach's α and composite reliability are also presented in Table IV. Reliability values over 0.7 are preferable (Cronbach, 1951; Nunnally, 1978) and a cut-off value of 0.6 is considered adequate (Nunnally, 1978; Li *et al.*, 2002; Chen and Paulraj, 2004). The Cronbach's α and composite reliability is greater than 0.7 for all constructs, for which they are over 0.6 indicating acceptable reliability of the measurement items. Prior to assessing the second-order measurement model we establish the second-order nature of all five second-order constructs. Table III presents the fit indices when the sub-dimensions of EE, IE, ERPI, supplier capabilities and performance outcomes are modeled as a first-order construct allowing for inter-dimensional correlations and as second-order constructs. The two models have equivalent fit indicating that all variables may be modeled as second-order constructs in line with its conceptualization. Table II presents the fit indices for the second-order measurement model. The fit indices indicate a good fit for the second-order measurement model. All items again load significantly on the posited constructs indicating convergent validity. Further, item loadings are similar between the first- and second-order measurement models indicating that the measurement is robust when specifying the second-order construct of all five second-order constructs. Tables IV and V present the inter-construct correlations,

Table III.
Fit statistics for validating the measurement model

Fit statistic	External environment (EE)		Internal environment (IE)		ERP implementation (ERPI)		Supplier capabilities (SCAP)		Supplier performance (SPERF)	
	First-order	Second-order	First-order	Second-order	First-order	Second-order	First-order	Second-order	First-order	Second-order
χ^2	10.484	10.484	223.085	263.959	110.09	122.508	78.797	78.797	133.666	133.995
Df	7	7	176	181	59	61	41	41	71	73
RMSEA	0.049	0.049	0.036	0.047	0.065	0.070	0.067	0.067	0.066	0.064
GFI	0.985	0.985	0.907	0.890	0.927	0.918	0.938	0.938	0.912	0.912
CFI	0.991	0.991	0.983	0.969	0.972	0.967	0.978	0.978	0.978	0.978
NNFI	0.981	0.981	0.979	0.965	0.964	0.958	0.971	0.971	0.971	0.973
IFI	0.991	0.991	0.983	0.970	0.973	0.967	0.978	0.978	0.978	0.978
SRMR	0.039	0.039	0.042	0.069	0.057	0.069	0.036	0.036	0.037	0.037

Construct	TC	RM	TM	OC	CM	BP	IT	IN	CF	AD	UT	CFC	IC	AG	SL	PV	CP	QL	Reliability Cronbach α	Composite reliability[a]
TC	(0.756)																		0.726	0.727
RM	0.660	(0.713)																	0.800	0.805
TM	0.403	0.334	(0.797)																0.900	0.874
OC	0.417	0.304	0.513	(0.845)															0.890	0.882
CM	0.121	0.087	0.390	0.547	(0.783)														0.850	0.822
BP	0.276	0.252	0.272	0.447	0.667	(0.714)													0.800	0.804
IT	0.140	0.041	0.305	0.419	0.711	0.637	(0.867)												0.930	0.924
IN	0.177	0.055	0.223	0.309	0.327	0.459	0.421	(0.854)											0.870	0.889
CF	0.160	0.130	0.285	0.360	0.327	0.517	0.392	0.789	(0.800)										0.860	0.841
AD	0.001	0.107	0.145	0.226	0.215	0.315	0.364	0.473	0.522	(0.936)									0.920	0.934
UT	−0.03	0.032	0.241	0.203	0.430	0.493	0.486	0.479	0.489	0.499	(0.865)								0.910	0.899
CFC	0.046	0.127	0.200	0.286	0.256	0.360	0.362	0.503	0.548	0.376	0.380	(0.791)							0.870	0.868
IC	0.209	0.091	0.367	0.508	0.325	0.500	0.399	0.519	0.629	0.412	0.385	0.681	(0.823)						0.880	0.863
AG	0.135	0.126	0.292	0.368	0.239	0.369	0.308	0.434	0.569	0.416	0.469	0.526	0.722	(0.899)					0.940	0.944
CP	0.258	0.162	0.335	0.393	0.226	0.451	0.322	0.490	0.541	0.378	0.373	0.509	0.663	0.465	(0.872)				0.930	0.927
PV	0.166	0.246	0.232	0.387	0.203	0.295	0.259	0.285	0.326	0.309	0.383	0.408	0.523	0.576	0.600	(0.923)			0.940	0.945
TM	0.307	0.161	0.249	0.339	0.154	0.278	0.210	0.338	0.407	0.291	0.242	0.428	0.524	0.552	0.603	0.573	(0.869)		0.890	0.902
QL	0.213	0.051	0.275	0.317	0.230	0.354	0.329	0.313	0.380	0.254	0.405	0.395	0.600	0.546	0.610	0.592	0.623	(0.891)	0.940	0.939

Notes: Average variances extracted are on the diagonal in parenthesis; [a]calculated according to Fornell and Larcker (1981)

Table IV. First-order inter-construct correlations, reliability, and discriminant validity average variance extracted and composite reliability values. They also verify discriminant validity for all constructs. Reliability values for all the constructs are over 0.7 indicating good reliability.

5.2 The causal model results

A SEM was used to test and estimate the causal relationships amongst various constructs (Bollen and Long, 1993). Since the reliability and validity of each construct were checked earlier, the SEM analysis focused on the structural model. Since it would be better to use several indicators of a construct than a single indicator, we used composite measures as multiple indicators for each construct (Hair *et al.*, 2009). Composite measures were calculated by dividing the sum of individual scores of items in each sub-construct by the number of items. These composite measures were used as observable indicators of the exogenous latent construct (EE) and endogenous latent constructs (IE, ERPI, SCAP, and SPERF).

As shown in Figure 1, we support *H1* that a firm which operates in highly uncertain, competitive and rapidly changing EEs will have a high level of adjustment and improvement in IEs as evidenced by a strong relationship between the EE construct and the IE construct at $\alpha = 0.01$ (with $\beta = 0.360$, $t = 3.441$). This result is consistent with the findings of Gordon (1991) and Nahm *et al.* (2003) that an organization's IE was often affected by its EE. On the other hand, we found a relationship between the EE and the ERPI to be statistically insignificant at $\alpha = 0.05$ (with $\beta = -0.076$, $t = -0.892$). Thus, we reject *H2* that a firm that operates in highly uncertain, competitive and rapidly changing environments is more likely to adopt and implement ERP. This result contradicts that of Grover and Goslar (1993) revealing that environmental uncertainty has a significant impact on the adoption of ICT. The explanation for this result is.

First, a firm may have implemented ERP, not because of the external pressure but because of its internal motive to improve organizational performance in more competitive business environments. Indeed, Premkumar and Ramamurthy (1995) observed that a firm could be motivated to adopt ICT due to its internal needs. Second, ERP may be no longer unique in today's business environments and thus has become a common practice for the firm seeking performance improvement regardless of its external environmental surroundings. To further examine a relationship between the EE and the ERPI, we estimated the coefficients of both total and indirect effects. The coefficient of a total effect between the EE and the ERPI constructs was calculated by adding the coefficient of both direct and indirect paths between them. The coefficient of the direct path between them was -0.076. The coefficient of an

Table V. Second-order inter-construct correlations, reliability, and discriminant validity

Construct	EE	IE	ERPI	SCAP	SPERF	Reliability Cronbach's α	Reliability Composite reliability
EE	(0.835)					–	0.818
IE	0.415***	(0.678)				–	0.807
ERPI	0.16	0.659***	(0.749)			–	0.832
SCAP	0.194**	0.637***	0.744***	(0.811)		–	0.851
SPERF	0.313***	0.559***	0.61***	0.755***	(0.775)	–	0.857

Note: Significant at: $^{*}p < 0.1$, $^{**}p < 0.05$ and $^{***}p < 0.01$

indirect effect was calculated by multiplying the coefficient of a direct effect (0.360) between the EE and the IE construct by that of a direct effect between the IE and the ERPI construct (0.790), resulting in 0.284. Thus, the coefficient of a total effect was 0.235 which turned out to be statistically significant $\alpha = 0.01$ (with $t = 2.14$). This result indicates that although the EE has no direct bearing on the ERPI, there was a positive and significant indirect relationship between the EE and the ERPI. In other words, a relationship between the EE and the ERPI was mediated through an IE (e.g. top management support, organizational culture, communication, business process reengineering, and ICT readiness).

Our AMOS analysis also indicates that the firm's IEs significantly influence its ERPI as evidenced by a significant positive relationship between the IE and the ERPI construct at $\alpha = 0.01$ (with $\beta = 0.790$, $t = 7.166$). This finding is consistent with the findings of several prior studies conducted by Motwani *et al.* (2002), Zhang *et al.* (2002) and Kwahk and Lee (2008) indicating that the firm's IE led to successful ERPI. For instance, organizational readiness and proper change management could lead to the successful implementation of ERP by mitigating the organizational resistance to ERPI. In fact, all the IE sub-constructs but organizational structure were proven to be critical for successful ERPI.

Although the impact of ERP on the individual firm was well documented by many prior ERP studies, its impact on the focal company's upstream supply chain partners such as a supplier has not been reported in the published literature. To assess the potential impact of ERP on SCAP, we checked to see if there exited any positive relationship between the ERPI and the SCAP. Our test revealed that ERPI significantly affected SCAP in a positive manner at $\alpha = 0.01$ (with $\beta = 0.833$, $t = 7.848$). This finding implied that a buying firm's successful ERPI could enhance its supplier's capability and thus could make the entire supply chain more resilient by solidifying business ties between the buying firm and its supplier. The rationale being that the ERP success facilitates information sharing between the buying firm and its supplier and subsequently enables the supplier to improve its demand forecasts, synchronize production and logistics activities, coordinate inventory planning, and then reduce supply disruptions and bottlenecks (Lee and Whang, 2000).

Finally, we checked to see whether improved SCAP can be translated into the supplier's improved performance. Thus, we tested a relationship between SCAP and the SPERF. Our test results revealed that SCAP had a significantly positive relationship with the SPERF at $\alpha = 0.01$ (with $\beta = 0.825$, $t = 8.856$). This finding is consistent with the RBV of Barney (1991), indicating that a firm's unique resources and capabilities tend to enhance its organizational performance. To elaborate, the supplier's improved capability resulting from faster information access, process improvement, and product innovation capabilities can contribute to the supplier's order fulfillment performances and the subsequent competitiveness in the marketplace.

6. Key findings and managerial implications

This section summarizes key findings of our ERP study and their practical implications for firms which must cope with the challenges of more volatile supply chain operations in an era of technological innovations.

First, the firm's ERP adoption and implementation decision is mainly affected by its IE. Defying the conventional wisdom, the firm's EE such as technological changes has little influence on its decision to adopt and implement ERP. However, through the mediating role of an IE, an EE still influences the ERP adoption and ERPI decision. This finding implies that the successful ERPI hinges on the firm's organizational compatibility with ERP. In other words, without garnering top management support, fostering the adaptive organizational culture, developing the open communication channel, stressing business process reengineering, and establishing the necessary infrastructure for new ICT adoption, the firm will encounter severe difficulty in reaping the full benefits of ERP. As such, before undertaking the ERP project, the firm should make sure that the ERPI would be led by senior executives who have the authority to make international cultural changes through cross-functional integration and high-velocity flow of information throughout the supply chain.

Second, we found that ERP could enhance the ERP adopter's SCAP. This capability includes the supplier's information accessibility, process improvement ability, product innovation skills, and the subsequent ability to mitigate the bullwhip effects. Since this improved SCAP could make the buying firm's supply base more reliable and stable, it would eventually help the buying firm not only reduce the risk of supply disruptions, but also increase the chance of new product development. Eventually, we learned that the improved SCAP would lead to the improved SPERF. That is to say, the ERPI could create "win-win" situations for both the buying firm and its supplier(s) and thus make their supply chain more resilient. This study is one of the first to discover the ERP's far reaching impact on the ERP's adopter's SCAP.

To better exploit ERP for supply chain operations, the potential ERP adopter should start with a feasibility study, the removal of internal functional silos, the establishment of a collaborative partnership with its supplier(s), user training/education, and development of ERP performance metrics. The feasibility study allows the potential adopter to check the suitability of ERP to its specific organization settings (e.g. organizational characteristics, culture, and ICT infrastructure) and supply chain needs (e.g. order fulfillment, demand planning). The removal of internal functional silos would facilitate the integration of internal business functions and thus eliminate redundancy and potential roadblocks. The establishment of a collaborative partnership with the supplier increases the chances of information sharing and the supplier's early involvement in new product development which would create "win-win" situations for both the ERP adopter and its supplier(s) through the ERP links. User training/education is essential because it would enhance the user's familiarity with ERP and thus mitigate any fear of uncertainty/risk associated with ERPI. Since it may take years for the firm to successfully implement ERP, the progress of ERP during transition from the legacy system should be monitored with specific performance metrics such as cash-to-cash cycle time, inventory turns, order fulfillment rate, customer responsiveness, and sourcing cost savings.

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Appendix

Constructs/items	
	External environment
Technological change (TC)	
D11TC1	In our industry, technology changes rapidly
D11TC3	In our industry, technological change transforms business practices
Rapid market change (RM)	
D13RM1	Our customers' order items are frequently changed
D13RM2	Our customers' order quantity is frequently changed
D13RM3	Our customers' expectations for the product price are frequently changed
D13RM4	Our customers' expectations for the product quality are frequently changed

Table AI.
List of survey items for operationalizing EE

Table AII. List of survey items for operationalizing IE

Constructs/items	
	Internal environment
Top management support (TM)	
TM1	Top management understands how the implementation of new technology will benefit the enterprise
TM2	Top management recognizes the need for long-term support for the implementation of new technology
TM3	Top management identifies the implementation of new technology as a top priority
TM4	Top management reinforces the commitment of all the employees to the implementation of new technology
TM5	Top management willingly assigns resources to facilitate the implementation of new technology as they are needed
Organizational culture (OC)	
OC1	We believe that investments in information technology increase creativity among our workers
OC2	We believe that investments in information technology support product innovation efforts among our workers
OC3	We believe that investments in information technology support process improvement efforts among our workers
OC4	We believe that investments in information technology increase intellectual work among our workers
Communication (CM)	
CM1	Expected outcomes of the project are communicated to managers
CM2	Expected outcomes of the project are communicated by upper management in advance
CM3	Expected outcomes of the project are shared among workers within departments
CM4	Expected outcomes of the project are shared among workers across departments
Business process reengineering (BP)	
BP1	We design and document important business processes
BP2	We appoint the best managers to be process managers
BP3	We measure our performance based on business process goals rather than functional goals
BP4	Functional managers support business processes
IT readiness (AG)	
IT1	IT staff is able to configure information systems
IT2	IT staff is able to efficiently implement system upgrades
IT3	IT staff is able to conduct a formal validation of all system changes
IT4	IT staff has high degree of technical expertise

Table AIII.
List of survey items for operationalizing ERPI

Constructs/items	
	ERP implementation
Integration (IN)	
IN1	We seamlessly integrate the modules in the ERP system
IN2	We seamlessly integrate all transactions in the ERP system
IN3	We seamlessly integrate the ERP system with SCM (customer or supplier relationship) system, using communication protocols and standards
IN4	We seamlessly integrate the ERP system with manufacturing management system, using communication protocols and standards
Configuration (CG)	
CG1	The ERP system meets all the needs of organizational processes
CG2	The ERP system accommodates the changes required by the organization's processes
CG3	The ERP system supports the business practices of our company (data fit)
Adaptation (AD)	
AD1	To align with changing organizational needs, we easily alter/append ERP data items
AD2	To align with changing organizational needs, we easily alter ERP input/output screens
AD3	To align with changing organizational needs, we easily alter ERP reports
User training (UT)	
UT1	ERP system users are provided with customized training materials for each specific job
UT2	ERP system users are provided training materials that demonstrate an overview of the system, not just help with the ERP screens and reports
UT3	ERP system users attend a formal training program that meets their requirements

Table AIV.
List of survey items for operationalizing Supplier Capabilities

Constructs/items	
	Supplier capabilities
Information access (IA)	
IA1	Our suppliers are able to retrieve information on their suppliers, customers and competitors
IA2	Our suppliers are able to access in-house databases on products they need
IA3	Our suppliers are able to gather and process data for our product preferences quickly
IA4	Our suppliers are able to gather and process data for fundamental shifts in the purchasing environment quickly
Process improvement (PI)	
PI1	Our suppliers are able to reduce delays in the distribution process
PI2	Our suppliers are able to reduce paperwork
PI3	Our suppliers are able to reduce wasted time and costs in all internal processes
Product innovation (PN)	
PN1	Our suppliers are able to develop products with unique features
PN2	Our suppliers are able to improve product quality
PN3	Our suppliers are able to develop products with better performance
PN4	Our suppliers are able to develop new products and features

Constructs/items	
	Supplier performance
Short lead time (SL)	
SL1	Our suppliers deliver products within a shorter time
SL2	Our suppliers improve the speed of service through eliminating waste and non-value added activities
SL3	Our suppliers have shorter throughput time
SL4	Our suppliers minimize the time from order placement to the delivery of procured items
Product variety (PV)	
PV1	Our suppliers provide new products with additional features anytime
PV2	Our suppliers provide new products with improved performance anytime
PV3	Our suppliers have a wide products offering
Cost performance (CP)	
CP1	After introducing an ERP system, our suppliers have lower production unit costs
CP2	After introducing an ERP system, our suppliers have lower material costs
CP3	After introducing an ERP system, our suppliers have lower overhead cost
Quality (QL)	
QL1	Our suppliers offer products that consistently conform to our specifications
QL2	Our suppliers offer products that are highly dependable
QL3	Our suppliers offer products that are durable
QL4	Our suppliers offer products that have lower defective rates

Table AV.
List of survey items for operationalizing SPERF

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